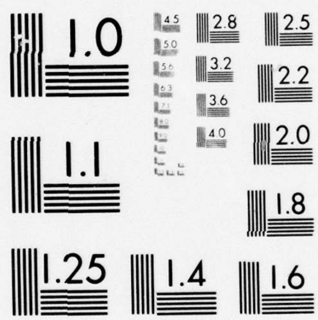
AD-A039 073 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 17/2
THE CURRENT STATE AND FUTURE OF OPTICAL INFORMATION TRANSMISSIO--ETC(U)
NOV 76 W BOTH
UNCLASSIFIED FTD-ID(RS)I-1298-76 NL

| OF |

AD
A039073

END
DATE
FILMED
5-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A039073

FTD-ID(RS)I-1298-76

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

THE CURRENT STATE AND FUTURE OF OPTICAL
INFORMATION TRANSMISSION

by

W. Both

FOREIGN TECHNOLOGY DIVISION

Approved for public release;
distribution unlimited.

FTD ID(RS)I-1298-76

EDITED TRANSLATION

FTD-ID(RS)I-1298-76 11 November 1976

FTD-76-C-001141

THE CURRENT STATE AND FUTURE OF OPTICAL INFORMATION TRANSMISSION

By: W. Both

English pages: 12

Source: Militartechnik, Nr 1, 1976, PP. 17-19.

Country of origin: East Germany
Translated by: LINGUISTIC SYSTEMS INC.
F33657-76-D-0389
K. Bennett Howe
Requester: RCA
Approved for public release; distribution unlimited.

THE CURRENT STATE AND FUTURE OF OPTICAL INFORMATION TRANSMISSION

W. Both

The discovery of the laser in 1960 and especially of the solid state laser (1962) for the first time permitted serious thoughts of efficient optical information transmission. In the first investigations the atmosphere was the transmission medium. The extremely high susceptibility to interference of this type of communication led to a search for new methods: hollow mirror tubes, lens conductors, and glass fibers were considered in order to exclude atmospheric influences.

After an examination of the components of an optical transmission channel the following report will show how the realization of optical information transmission is possible and will consider the military aspects.

1. LIGHT EMITTER

Since the information transmission takes place in the optical range of the spectrum the electrical signals (telephone, radio, or data channel) must be converted into light pulses. The GaAs luminescent diode and the laser diode are available here as radiation sources.

Semiconductor lasers are well suited for optical information transmission for several reasons. The good efficiency,

the small size, and the property of being able to operate continuously at room temperature appear advantageous. The GaAs laser diode developed in 1962 was built up from the simple hetero-structural diode to the double hetero-structural diode.

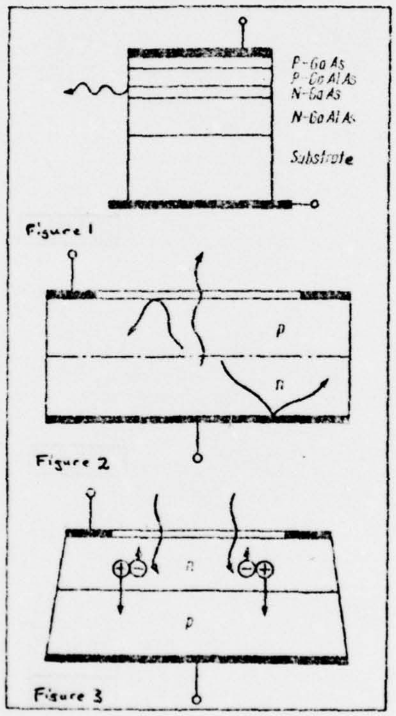


Figure 1. Double hetero-structural laser diode

Figure 2. Luminescent diode

Figure 3. Photodiode

Here the optically active GaAs layer is embedded in GaAlAs layers (Fig. 1). The high threshold current densities necessary could thus be lowered (10^3 to $2 \cdot 10^3$ A/cm^2). These also limit the service life very considerably. $6 \cdot 10^2$ hours have already been reached in laboratoryinvestigations, $6 \cdot 10^4$ hours are expected, but at least 10^5 hours are necessary for reliable

operation. Surely further success will be achieved /1/ through optimization of a large number of the factors (further development of the mesa and strip geometry, heat sink, film parameters, construction). At the present time laser diodes already are modulable in the case of low load ratios (1:100 to 1:1000) over the pump flow up to the gigahertz range. There is still room for improvements; thin film lasers also appear to be acceptable variants for the future /2/.

Luminescent diodes are already available and reliable radiation sources at the present time. The emission takes place upon the recombination of the injected carriers in the p-n transition zone.(Fig. 2). Therefore the radiation emitted is incoherent (in contrast to lasers). The spectral range is from 35 to 40 nm. The middle frequency of the radiation can be adjusted by varying the doping of the gallium /3/. GaAsP (650 nm), GaP (560, 590, 690 nm), GaAs (900 nm), and GaAlAs (750 to 900 nm) are the most important compounds used. The optical performance is below that of the laser; at any rate the reliability is great from $\lambda = 10^{-5}$ to 10^{-6}. This does not mean a failure, but rather a drop of 50 percent in the initial emission. The maximum modulation frequencies, however, are about a power of ten below that of the laser.

Luminescent diodes, like laser diodes, have a small emitting surface and are easy to combine with optical fibers. The The transition losses can be held small (0.4 to 0.5 dB). The

optical window of the atmosphere and a region of little damping for glass fibers can be used by both. A simple intensity modulation over the currect is possible up to high frequencies. Because of the low reliability of the laser diode, the first optical information systems presumably will operate with luminescent diodes.

2. PHOTODETECTOR

A number of components are available as photocells. However, only secondary photomultipliers and photodiodes are suited for reliable information transmission. Secondary photomultipliers are highly sensitive and have an adequate band width. Because of the high voltages necessary, however, they can not be integrated well into semiconductor circuits. Photodiodes do not display this disadvantage and possess the same sensitivity and band width. A transformation of light energy into electrical current is possible here by means of the utilization of the photoelectric effect (Fig. 3). The following relationship holds true:

$$i(t) \quad \frac{\eta \cdot e \cdot p(t)}{h \cdot \nu}, \qquad (1)$$

$i(t)$ - current, η - quantum efficiency, e - electronic charge, $p(t)$ - light energy, $h \cdot \nu$ - photon energy.

Primarily photodiodes based on silicon are used because of the low noise. These display a high sensitivity and short

transition times (>5 ns) within the already mentioned optical window. The spectral sensitivity can be controlled by varying the p-n transition within the limits. The diode types are differentiated according to the structure. A p-i-n structure is possible in addition to the simple p-n constructure. These photodiodes have short response times. A significant improvement of the signal-noise ratio can be obtained from the use of avalanche photodiodes. Avalanche photodiodes have an internal amplification effect as a result of ionization by collision. They are of particular use in the case of high rates of information to transmit. Like the light emitters already considered, the receivers are easily combined with optical fibers because of their small sensitive surfaces. The resulting current (see equation 1) is proportional to the light energy (in a wide range), and the diode may be integrated into semiconductor circuits. The band width and reliability difficulties are ignored here. Of course, at present there are neither senders or receivers which permit easy coupling with optical fibers or are already coupled.

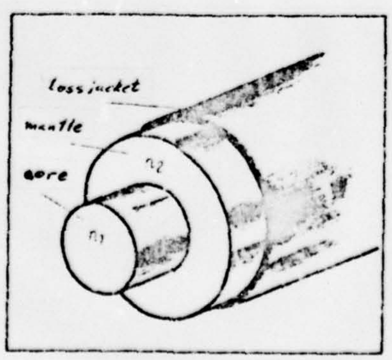


Figure 4. Fiber construction.

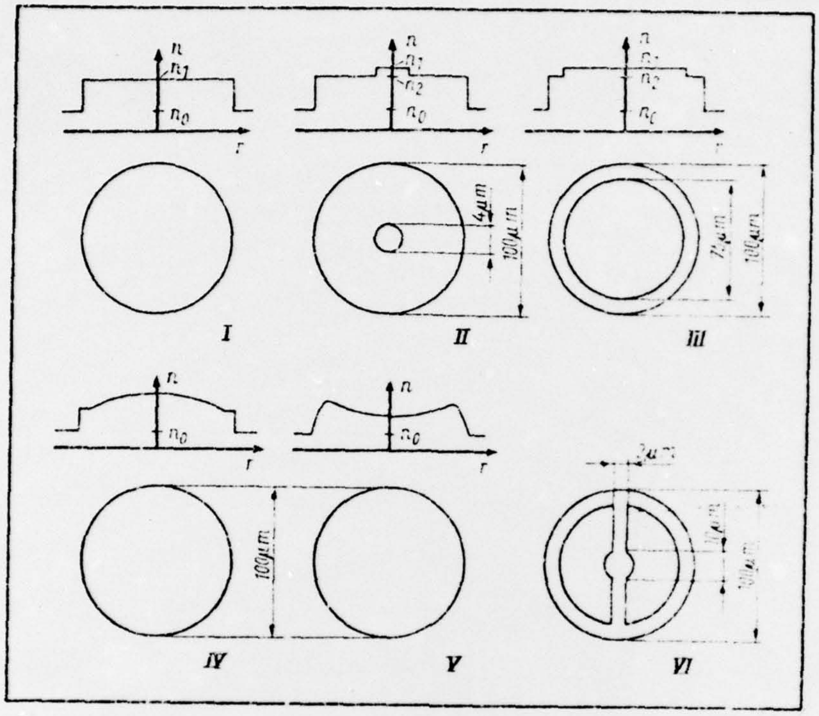


Figure 5. Fiber cross-section (according to /11/)

3. OPTICAL FIBERS

An optical fiber can be conceived of as a cylindrical dielectric surface wave guide. The light propagation along the fiber axis is described by the propagation modes. Modes are understood as being distribution forms of the electromagnetic field. A mode or several modes are capable of propagation according to the boundary conditions (refractive index, wave length, diameter of the fiber core). Accordingly, basically two types of fibers are distinguished: monomode and multimode fibers. In the case of the first one the diameter of the core is small (3 to 5 μm). The core diameter of the multimode fibers

is between 50 to 100 μm).

Figure 4 shows the fundamental layer structure of a glass fiber and Fig. 5 shows some fiber cross-sections with the appropriate refractive index curve over the diameter. Type I represents the fiber, already designed by 1910, which uses the index difference between glass and air. Type II is the monomode fiber, and type III is a multimode fiber. Both display an index jump and are designated as core-mantle fibers. Types IV and V, on the other hand, display a continuous variation; they are called gradient fibers. Type VI represents a fiber which was introduced by the American firm Corning Glass Works. The coaxial structure consists of a type of glass. The minimum measured damping is 2 dB/km /4/.

In practice it is not possible to obtain the theoretically calculated channel capacity. Fig. 6 shows the spectral damping of a multimode fiber. There are different factors which influence the losses significantly. Thus, for example, the damping maximum at 950 nm is to be attributed to a resonance of the oxygen-hydrogen bond of water. Small impurities from metals have a great influence, as do bends and inhomogeneities. In the case of multimode fibers there is a further reduction from dispersion phenomena. Fig. 7 shows the beam path in a core-mantle fiber. It is recognized that the axial beam has to cover a shorter distance than the one travelling at the critical angle. A narrow light pulse, the energy content of which splits into

individual beams therefore will appear expanded at the output end. Experimental investigations showed that this expansion is proportional to the differences in transit time $\sqrt{l}$ /5/. The use of other index curves results in a reduction of this so-called mode dispersion. Gradient fibers represent the result of optimization investigations.

A further form of the dispersion results from the frequency dependence of the refractive index. If light pulses are emitted from a broad-band source ther is an additional expansion. There is a material dispersion of around 3.6 ns/km for a spectrum of 36 nm (typical luminescent diode).

4. OPTICAL SIGNAL TRANSMISSION

The transducers and transmission elements considered in sections 1, 2, and 3 are the critical components for an optical information channel (Fig. 8). From the USA it is known that the US Defence Department is allocating 30 million dollars for the development of a fiber optic information system. At the same time, transmission in the atmosphere plays a smaller role. According to /6/ it is entirely possible to determine the disturbances - produced by absorption phenomena, scattering, turbulence, or beam deflection - over a larger period of time for a limited area and to obtain transmission reliabilities of 90 to 99 percent by means of properly dimensioning the receivers. However, military operations entail great changes in the atmos-

phere so that use in the military sector appears unsuitable. A dimensioning which seeks to consider all variations would be uneconomical. Only a limited application (data, telephone, or television in industrial networks) is found even in the civilian sector. The use of atmospheric communication by optical means over short distances could be of interest, e. g. cordless transmission of speech signals in tanks, aircraft, or ship's holds. Infrared emitters and receivers are appropriate here since IR undergoes no absorption on dark or rough surfaces.

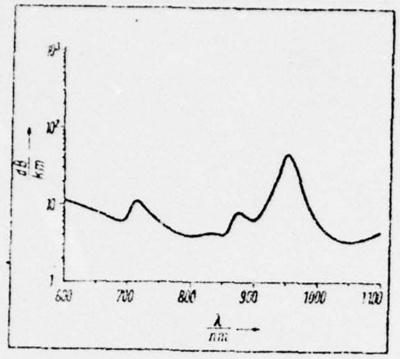
The use of optical fibers is known from the Soviet Union and the USA /7/, /8/. Heavier copper coaxial cables are being replaced by glass or plastic fibers both in ships and in aircraft. The connection of peripheral units with the central unit of computers also is possible. Further, the Office of Development of the US Army is collaborating with a company to develop glass fiber cables as a communication medium between command posts and front lines /9/. An expansion of the band width by 10^5 will be obtained by replacing copper cables. A 6-fiber cable with a diameter of 3 mm has already been introduced, and a 26-pair cable is being worked on at the present time. High tensile and compressive loads are achieved by means of plastic coating and sealing. It is hoped that the cost can be reduced to 1.65 dollars per meter. Further price reductions in fiber technology and increasing the number of high-speed transducers will make a glass fiber system economically superior

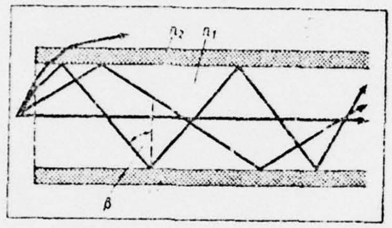
not only with full utilization of the available capacity. It would be possible to create a new kind of network structure /10/. A network with decentralized transmission offers a number of advantages:

- no central space requirement,
- no possibility of central disruption,
- standardized technology,
- great expansibility, and
- integration of all services.

A network of this kind would no longer possess any central facilities, the breakdown of which would disturb the entire network. Limited work would go on even in the case of cable breakdowns. Further advantages result from the use of glass fiber cables:

- small dimensions,
- low weights,
- small radii of bending (a few cm),
- inexpensive,
- wide band transmission medium,
- rectification solved almost completely by signal and cable optimization,
- inductionless, free of cross-talk (safety from interception), and
- low maintainence, no interference from humidity and temperature.





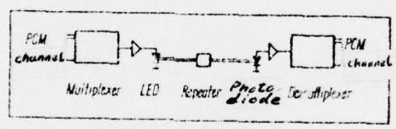


Figure 6. Spectral damping (multimode fiber)

Figure 7. Wave path in a core-mantle fiber (total reflection)

Figure 8. Fiber optic system

Particular attention should be given to the low content of potassium and radium. Hard radiation, which appears particularly in the case of the detonation of nuclear weapons, changes the optical properties of glass. Fluorescence appears under the influence of hard radiation, that is, the light reception is disturbed by additional photons. This effect can be damped with plastic jackets and by burying.

5. FINAL REMARKS

The prospect of being able to replace 10 kg of copper with 1 g of glass with the same channel capacity demonstrates the significance of glass fiber systems. However, a great deal of work in the area of construction technology still is necessary before complete utilization and economical production of these systems are possible. In addition to laying and splicing techniques still to be developed, a further miniaturization imposes high tolerance demands. Transducer elements with high coupling factors and inexpensive glass cables with low damping and high reliability must be developed. It can be demonstrated that this wide band transmission has a future.

REFERENCES

[1] Fortschritte in der Glasfasernachrichtenübertragung. Funktechnik, Berlin-West 1974, H. 23, S. 819–821.

[2] Bose, H., Kube, E.: Nachrichtenübertragung in Lichtleitern. Nachrichtentechnik, Berlin 24 (1974) 10, S. 379–382.

[3] Swetschnikow, S. W.: Elemente der Optoelektronik. Moskau 1971.

[4] Gloge, D.: Optische Fasern für die Nachrichtenübertragung. Applied Optics, Easten 13 (1974) 2, S. 249–54.

[5] Chinnock, E. L., u. a.: Längenabhängigkeit der Impulsverbreiterung in der CG'W-Bell 10 Faser. Proceedings of the IEEE, New York 52 (1973) 2, S. 1499–1500.

[6] Kube, E.: Optische Nachrichtenübertragung mit Halbleiterstrahlungsquellen. Nachrichtentechnik, Berlin 22 (1972) 3, S. 90–93.

[7] Armeeentwicklungen für Faseroptik. Electronics, New York 48 (1975) 3, S. 44.

[8] Talysin auf 1. wiss.-techn. Allunionskonferenz der Hochschulen für Nachrichtentechnik. Moskau 26. 1.–31. 1. 1975.

[9] Armee entwickelt Faseroptikkabel für Frontlinien. Electronics, New York 48 (1975) 1, S. 29–30.

[10] Ohnsorge, H.: Neue Möglichkeiten für Nachrichtensysteme auf der Basis des Laser-Glasfaserkanals. PTT-Mitteilungen, Bern 1973, H. 1, S. 19–25.

[11] Marcatili, E. A. J., u. a.: Forschung über Glasfaserübertragungssystemen. Proceedings of the IEEE. New York 61 (1973) 12, S. 1705.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER FTD-ID(RS)I-1298-76	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* THE CURRENT STATE AND FUTURE OF OPTICAL INFORMATION TRANSMISSION		5. TYPE OF REPORT & PERIOD COVERED Translation 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR*(s)* W. Both		8. CONTRACT OR GRANT NUMBER*(s)*
9. PERFORMING ORGANIZATION NAME AND ADDRESS Foreign Technology Division Air Force Systems Command U. S. Air Force		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1976 13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

17; 09

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE
A205	DMATC	1
A210	DMAAC	2
B344	DIA/DS-4C	8
C043	USAMIIA	1
C509	BALLISTIC RES LABS	1
C510	AIR MOBILITY R&D LAB/FIO	1
C513	PICATINNY ARSENAL	1
C535	AVIATION SYS COMD	1
C557	USAIIC	1
C591	FSTC	5
C619	MIA REDSTONE	1
D008	NISC	1
H300	USAICE (USAREUR)	1
P005	ERDA	2
P055	CIA/CRS/ADD/SD	1
NAVORDSTA (50L)		1
NAVWPNSCEN (Code 121)		1
NASA/KSI		1
544 IES/RDPO		1
AFIT/LD		1

ORGANIZATION		MICROFICHE
E053	AF/INAKA	1
E017	AF/RDQLR-W	1
E404	AEDC	1
E408	AFWL	1
E410	ADTC	1
E413	ESD	2
	FTD	
	CCN	1
	ETID	3
	NIA/PHS	1
	NICD	5